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Bridge Monitoring & Assessment via OSMOS Optical Strands

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ABSTRACT

Knowing the actual level of traffic on a road bridge and its consequences in terms of stress cycles in the bridge structure is of great value in the scheme of a resilient asset management. A solution is proposed in the case of different types of road bridges in Europe, based on continuous strain monitoring by the mean of Optical Strands sensors and of dedicated analysis tools provided by OSMOS Group.

The choice of performing continuous strain measurements on critical parts of the bridge deck is discussed, as a relevant solution in order to provide the control of the actual effects of exceptional convoys on the structure, the automatic detection of heavy vehicles with an estimation of their actual weight, and the assessment of the structural elements in terms of strain and stress, both under the effects of the live loads and over the long term.

As the monitoring device is conceived as a permanent solution for these bridges, the accumulated data over several months allow a statistical analysis of the effects of heavy traffic in order to perform a fatigue analysis from comprehensive data instead of sampled ones. By considering some assumptions on the long-term growth rate of the traffic, an estimation of the lifespan of the asset is then performed.

The heavy traffic monitoring of road bridges through continuous strain measurements over long periods as proposed by OSMOS is an integrated solution which answers to several different problematics, both for the daily management through detection of overweight vehicles, and for the long-term assessment through lifespan estimation.

I. INTRODUCTION

A. *Generalities*

The structural health monitoring of works, buildings, infrastructures, are industrial equipment is in full expansion.

A McKinsey study in October 2017 estimated that US$3.7 trillion needs to be invested each year to 2035 in order to support current growth rates (Source: McKinsey Global Institute, Bridging Infrastructure Gaps, October 2017).

At the same time that our infrastructures are significantly growing, the world is hit by waves of natural disasters, year after year. As an example, in 2017, according to Swiss Re, the financial losses from earthquakes, hurricanes, floods, wildfires amounted to 337 B$US.

In parallel, the major part of the infrastructures (including bridges) have been built during the last century with life-limited materials and processes. Sized and built to last on average 80 years, many bridges are now at the end of their lifetime and are therefore at risk.

As an example, in the United States, by 2020 “aging and unreliable” infrastructure will cost the country’s businesses 1.2 trillion US$! All the critical infrastructures areas are impacted: transportation; energy; water; and communications. The U.S. has 614,387 bridges, in which 39% are 50 years or older, and 54% are 40 years and older. Most of the bridges were designed with a lifespan of 50 years! One in eleven (9.1%) of the country’s bridges were structurally deficient in 2016. The financial requirement to rehabilitate the bridges across the United States is enormous, estimated at $123 billion (Source : ASCE’s 2017 Infrastructure Report Card).

Similar figures (proportional to GDP and population) exists to other key markets in Europe (e.g. Italy, France, and Germany) and in Asia (e.g. Japan).

It is believed that the combination of three elements:

1. Colossal amounts of aging infrastructures;
2. Huge losses of infrastructures due to natural disasters and climate change; and
3. Massive need for new infrastructures;

combined with the newly to be introduced SHM regulation will drive the need for monitoring systems (climate, structural health, geotechnical, weather, etc.) to record high figure (over 10 B US$ business by 2022).

B. *Why SHM of Bridges is required?*

More specifically, the lifetime’s duration of the infrastructures, such as bridges, is impacted by two factors which are usually not considered in the design of the works:

1. An ever-increasing pollution and the multiplication of natural, climatic extreme events (earthquakes, floods, violent winds, etc.)
2. The intense circulation and growing number of trucks, and their respective weight

Thanks to the development of digital sensing technologies, telecommunications and the algorithmic processing of data in real time, it is today possible to supplement the visual inspections by a continuous monitoring, in real time, using intelligent sensors, and data acquisition & transmission systems, and a treatment by algorithms of the mass of data being collected.

This allows us to:

(i) know the state, the behavior and health of the works, and to follow them continuously and in real time to ensure safety;
(ii) streamline the maintenance required for the existing works;
(iii) prioritize the replacement of the works that can become defective; and
(iv) provide to the manager of bridges the "Toolbox" to manage the flow of trucks in function of their weight, so as to optimize the service while checking the safety of the works (weigh-in-motion augmented by deformation information).

C. *Rationale and Benefits for Integrated Structural Health Monitoring (ISHM)*

The environment, the dynamic events, and lifecycle affects over time the quality, the stability, the behavior, the availability, the performance, and sometimes the safety of the asset.

It is difficult, complex and almost impossible to predict natural disasters. However, it is feasible to monitor infrastructure (structural) assets in real time and continuous mode before, during and after natural disasters.

Monitoring assets can provide a base for preventive & predictive maintenance. With today's state of technology:

I. We can monitor these phenomena around the world, or for specific regions/locations;
II. We can monitor through time these phenomena for specific locations, structures, facilities;
III. With real time/continuous monitoring, we can evaluate the impact(s) of these phenomena before, during and after these events;
IV. We can collect a multiple of data/parameters over time to derive specific information using mathematical, physical and statistical algorithms;
V. We can match the various data & information collated with specific events to enable building (on a local and/or regional basis) Big Data for our structural asset owners;
VI. Through Big Data we can develop predictive analysis for improving the safety of people and optimizing maintenance, repair, rehabilitation

In summary we offer the following innovative holistic approach:

1. Continuous and Real Time Data Monitoring;
2. Data Analysis and Interpretation using Algorithms;
3. Machine Learning and Artificial Intelligence;
4. Preventive and Predictive Analysis; and
5. Integrated Intelligent Data Management System.

II. ASSESSMENT OF BRIDGES UNDER THE EFFECTS OF LIVE LOADS

A. *The past and the present*

In older practice, condition assessment and structural evaluation of existing bridges was mainly based on visual inspections complemented by Non-destructive Testing (NDT) and Evaluation (NDE) techniques, leading to precarious results. The empirical and conservative nature of these methods coupled with the subjective character of the inspections can lead to long-lasting lane exclusions, temporary or permanent bridge closure, time-consuming detours or even replacement of the bridge. On-site inspections can only disclose faults limited to the surface of the structure, at a single moment in time, factors that complicate and make uncertain any conclusions regarding the extent of deterioration and the underlying structural health of the bridge. In addition, even common structural analysis can lead to unsatisfactory conclusions since the actual performance of most bridges is more favorable than conventional theory dictates. For instance, the participation of secondary members in the overall stiffness, the unintended composite action between the deck and the beams or the portion of load that might be carried by the deck, are factors that enhance the load-carrying capacity of a bridge and can be ignored in conventional calculations.

Against this background, it is clear that the assessment of bridges should be implemented by means of new technologies and contemporary monitoring systems (State-of-the-art).

The Optical Strand system is based on high-precision sensors that measure deformations between two points with micrometric resolution. OSMOS has harnessed optical-waveguide technology to allow measurements of structural changes with a frequency of up to 100 Hz which makes it possible to carry out a continuous recording and to detect dynamic phenomena such as vehicle passages on bridges, earthquakes, shocks, etc. This technique provides extremely stable and reliable solutions with an optimized price/performance ratio and minimized requirements for electronic and mechanical components. The numerical signals, data, are obtained either through wired based systems and/or wireless based system and are transformed into information through advanced hardware, software systems, and innovative mathematical and statistical algorithms.

Thus, depending on the case, the necessities, the urgency and the available budget, OSMOS has advanced an integrated methodology for the assessment of bridges, concerning both short-term and long-term monitoring.

B. *Short-term Bridge Assessment*

OSMOS short-term (fast track) method estimates the real behavior of the structure and results in a holistic quantification of bridge's state through a rating system. Due to the absence of regulatory tools, the developed methodology is based on the fundamental design resistance equation and the practices of US standards (AASHTO The Manual for Bridge Evaluation, 2011). The applied method combines load testing and monitoring procedures in order to effectively and accurately determine the residual load carrying capacity and, depending on its rating, assure for the safety of a bridge, or the possible need for repair or replacement. In comparison to traditional methods, this process minimizes uncertainties regarding material properties, boundary conditions, impact of defects or hardly detectable damage, etc. and focuses on assessing the condition of a bridge, with the application of a sophisticated system of sensors (embedded or attached) that provides continuous measurements, thus allowing to record and evaluate the response under the effect of varying imposed live loads.

This method re-examines and revises the theoretical response of the bridge (calculated by the static model) in order to reflect the actual structural behavior resulted from the load test.

The developed static model is basic, without accounting for material or load safety factors given in the regulatory tools. The material properties could be ideally identified through NDTs procedures, otherwise mean values should be taken into account. In this way, the results of the load test can be directly compared to the ones of the model, within the scope to further investigate the actual correlation between theory and reality.

During the test, the imposed loads are placed at different positions of the deck to determine the response in all critical members, while linear behavior is controlled by continuous monitoring. Specifically, the intended load is imposed gradually (i.e. 25%, 50%, etc.) in order to examine the linear or non-linear behavior of the structure, since residual deformations are not acceptable during the test. An adjustment factor K as described in the AASHTO manual is determined which correlates the results of the load test with the theoretical response of the bridge in live loads, according to the equation below:

$$K = 1 + K_a \times K_b \tag{1}$$

where K_a = relates the test results to the theory
K_b = indicates the level of test benefit

In particular, K_a is calculated as:

$$K_a = \frac{\varepsilon_c}{\varepsilon_t} - 1 \tag{2}$$

where ε_c = strain value calculated by the model
ε_t = maximum measured strain value

The factor K_b takes into account the linearity or non-linearity of the structure during the load test and the magnitude of the imposed load compared to the design load. The values of K_b are given in the following table.

Table 1. Values of K_b

Behavior	Magnitude of Load Test		K_b
	$L_T \leq 0.7L_{Ed}$	$L_T > 0.7L_{Ed}$	
Linear	✓		0.8
		✓	1.0
Non-linear	✓		0
		✓	0.5

where L_T = imposed load of the test
L_{Ed} = design load

If $K > 1$, the static model underestimates the actual strength of the member. On the other hand, if $K < 1$, the actual response is more severe than the anticipated.

A rating factor is calculated that reflects the theoretical resistance of each critical member to live loads according to the equation below:

$$RF_{theor} = \frac{Capacity - Factored\ Dead\ Load\ Effect}{Factored\ Live\ Load\ Effect} \tag{3}$$

The abovementioned factor multiplied by the adjustment factor gives a revised one which accounts for the real resistance according to the following equation:

$$RF_{rev} = K \times RF_{theor} \tag{4}$$

where RF_{rev} = revised rating factor
RF_{theor} = theoretical rating factor
K = adjustment factor

If $RF_{rev} > 1.5$, the examined member is assessed as "safe" and its overstrength is reflected in the rating. In case, $1.0 < RF_{rev} < 1.5$, the member is assessed as "conditionally safe" and further investigation procedures should be applied (NDTs, advanced modelling analysis, etc.). Finally, if $RF_{rev} < 1.0$ the member is assessed as "non-safe" and its substrength is also reflected in the rating.

The final rating of the bridge derives from the least favorable rating of the critical members.

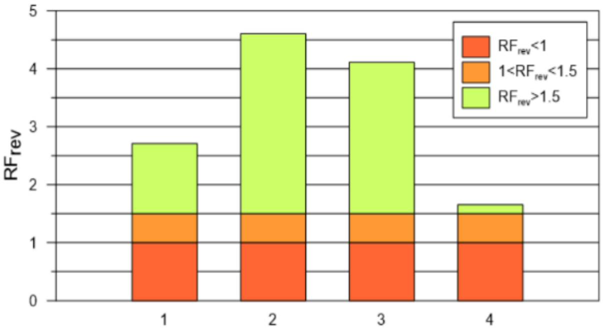


Figure 1. Load Rating of 4 bridges in Ptolemaida

In addition, via this procedure the dynamic characteristics of the bridge can be estimated. During the load test, any induced dynamic event is recorded by OSMOS sensors (optical strands) and the measurements (strains) are used to determine the natural frequency of the bridge through FFT analysis (Fast Fourier Transform).

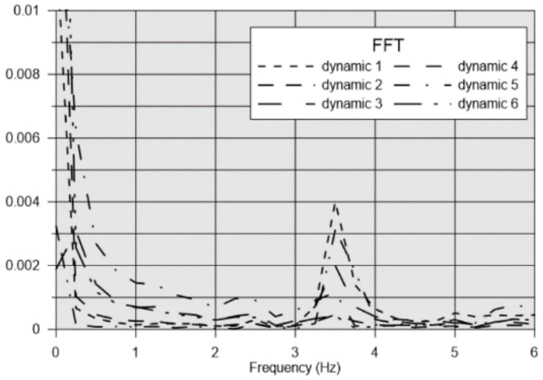


Figure 2. Fast Fourier Transform of dynamic events on a bridge in Crete (A90)

After the completion of the load test, the results are extrapolated to the new revised model, through which the behavioral response of the bridge is evaluated.

In Greece, several bridges of the Greek National Highway network have already been assessed through the aforementioned methodology. Until now, all the examined bridges in Northern (EGNATIA ODOS S.A.), Central (AEGEAN MOTORWAY S.A.) and Southern Greece (A90) were submitted to load tests which revealed that the static models had significantly underestimated their actual strength.

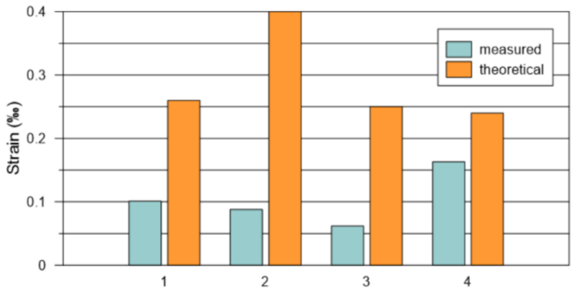


Figure 3. Comparison of the theoretical and measured strain values of 4 bridges in Ptolemaida

It is interesting to emphasize on a specific bridge of the P.A.TH.E. Highway (Central Greece) where the transit of heavy vehicles had been forbidden. After the completion of the load test, the assessment of the results found a rating factor $RF_{rev} = 1.8$ which proved that the strength of the bridge was critically underestimated. Concessionaire’s evaluation resulted in the release of the bridge, thus profiting by the tolls’ financial exploitation and benefiting by the avoidance of unnecessary repair costs.

C. *Long-term Bridge Assessment*

The long-term bridge assessment follows the same principles of the short-term assessment philosophy. Through long-term monitoring and statistical analysis of the collected data, any exceedance of the serviceability or strength limit state is detected. The limit states are determined by the static model of the bridge which is being recalibrated continuously in order to reflect the actual structural behavior resulted from the monitoring. In this way, the bridge is monitored constantly under the effect of ordinary live loads or other seasonal factors and an early warning can be given in case of emergency.

Considering all the above, OSMOS based on technological advancements in the field of Structural Health Monitoring (SHM) provide diagnostic methods that can verify the distribution of loads, quantify the bridges’ response to various loading conditions, and coupled with model calculations, determine the load bearing capacity of bridges. Moreover, OSMOS smart fiber optic sensors, by measuring real time micro deformations and stress variations on bridges via fiber micro-bending principle, provide an accurate tracking of structural soundness and behavior by timely detecting structural degradations, their occurrences and their locations. The assessment of the structural integrity can extend the lifespan of bridges that are in need of significant repairs or are approaching their expected time serviceability limit and is imperative in the effort to deal with deteriorating bridge infrastructure that inadvertently may incur significant human or capital losses.

III. INNOVATIVE WIM SOLUTION FROM STRAIN MEASUREMENTS ON THE BRIDGE DECK

A. *General Principle of B-WIM*

Performing Weigh-In-Motion from Bridge structure deformation (“B-WIM”) has been an active research field in the past years (Lydon *et al.*, 2016, Yu *et al.*, 2016). On-field experiments have been reported in Europe (Schmidt *et al.*, 2016) and in the USA (Hitchcock *et al.*, 2012) but there is no widely spread commercial application on the market yet.

B-WIM consists in using the influence lines of measurable effects of the live loads, like the bending of a bridge span, in order to deduce the actual weight of the vehicle driving on the bridge.

The analysis of the measurements usually involves deconvolution of the influence lines in order to get an estimation of successive axle weights, eventually combined to get the gross weight of the vehicle. This implies to use a sufficient number of sensors in order to measure relevant combinations of influence lines whatever the transverse location of the vehicle. The smoothing of dynamic effects like additional vibrations may also induce difficulties, especially when the period of the vibration is similar to the width of an axle's influence line in the time domain at usual speed.

B. *The OSMOS WIM+D Solution*

A new B-WIM solution has been implemented by OSMOS since May 2018 on a highway overpass in Europe (location is confidential). This solution called "WIM+D" relies on strain measurements on specific elements of the bridge span by the mean of Optical Strands.

Compared to previous B-WIM techniques, the novelty of the OSMOS WIM+D solution is to radically separate the estimation of Gross Weight and Axle Weight.

Gross Weight is obtained from sensors which measure global effects on main elements, where it is easier to smooth vibration effects and to get accurate influence lines. Meanwhile, the number of sensors required for this estimation whatever the transverse location of the vehicle is reduced to the number of main longitudinal elements of the bridge deck, usually 2 or 4 only.

The speed of the vehicle is computed as well, by checking the time gap between measurements from the sensors dedicated to the Gross Weight estimation and additional sensors located on a next span.

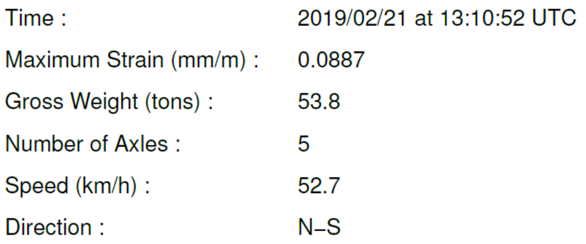
The Axle Weight is obtained from additional sensors which are sensitive to local effects, like the bending of the floor slab. Only one Axle Weight Sensor is required for each traffic lane over the bridge, which is typically 2 sensors on usual road bridges. The Axle Weight is computed by distributing the previously estimated Gross Weight on the several axles identified by the Axle Weight Sensors, with ratios deduced from the relative amplitude of the local effect for each axle.

C. *Case Study: Highway Overpass*

The highway overpass chosen as a pilot project is a composite deck with two main steel beams and a concrete floor slab, which supports two traffic lanes in opposite directions. It has two symmetrical 28m long spans.

Gross Weight and Speed Sensors are installed at mid-span on the lower flange of the main steel beams. Axle Weight Sensors are installed under the concrete floor slab in the space between the two main beams. The WIM+D solution in this case requires 6 sensors only. All of them are 1m long Optical Strands connected to an Expert Data Acquisition System which performs continuous measurement synchronization at a 100 Hz sampling rate.

The raw data is sent to the OSMOS cloud every 30 seconds. The WIM+D algorithm performs the data analysis on the cloud and releases comprehensive Passage Data Sheets for every single truck over the bridge on a Web Interface named Safe WIM+D within a 1 min average delay (Figure 4, 5 and 6).



Time : 2019/02/21 at 13:10:52 UTC
Maximum Strain (mm/m) : 0.0887
Gross Weight (tons) : 53.8
Number of Axles : 5
Speed (km/h) : 52.7
Direction : N–S

Figure 4. Typical results on a Passage Data Sheet

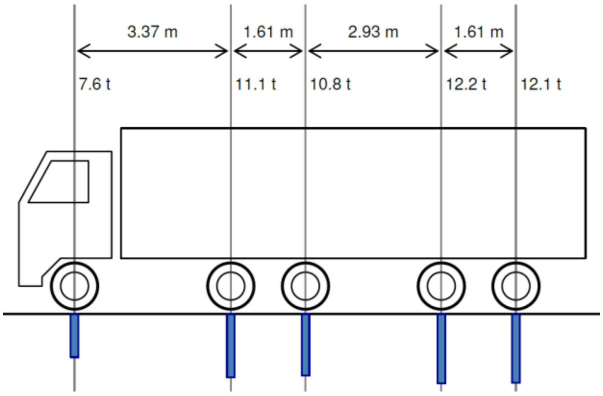


Figure 5. Truck Configuration as displayed on the Passage Data Sheet

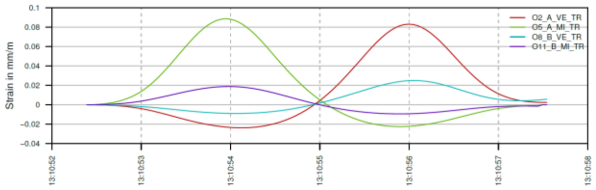


Figure 6. Strain Measurements as displayed on the Passage Data Sheet

D. *Load Test Results and Accuracy*

Load tests with five different trucks in terms of weight and configuration were performed early May and end of July 2018 in order to calibrate and test the accuracy of the WIM+D system.

Each truck made at least four different runs on the bridge: 2 runs in each direction, at low speed and normal speed. In addition, runs with trucks following themselves at short distance or coming from opposite directions at the same time were also performed. A total of 87 runs was used, distributed on the two different load tests with different environmental conditions.

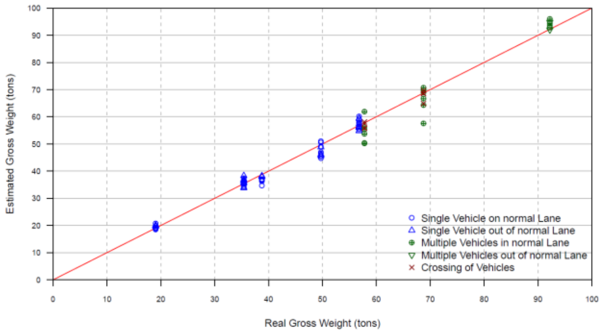


Figure 7. Load test results for 87 runs: Gross Weight

The results of the load tests show a good neutrality to environmental conditions, with no significant difference between runs performed early May or end of July (Figure 7).

The comparison of estimated gross weight with real gross weight gives a maximal error of 8.7% and an average error of 3.7% for single vehicles, with an average absolute error of 1.9 tons. The performance is similar in the case of vehicles crossing themselves on the bridge: in this case the ability of the algorithm to distinguish the two vehicles coming in opposite directions is well checked.

A statistical analysis according to COST323 has classified the WIM+D system in Class B for the Gross Weight.

The maximal error on axle weight is 15% for heavy axles of more than 10 tons and the average error is 7.5%. Lighter axles may have higher relative errors but the absolute error is always less than 2.5 tons and the average error is 0.8 tons. The maximal error on axle spacing is 0.40m and the average error is 0.15m. The axle weighing of the WIM+D system is subject to active research for further improvement nowadays.

E. *Traffic Statistics*

Once the WIM+D is calibrated and tested, it is able to automatically detect any truck which induces significant strain variations in the elements monitored by Optical Strands. Because of the high resolution of the sensors, this is sufficient even for relatively light vehicles, depending on the flexibility of the bridge deck. The usual application is to detect vehicles exceeding a significant weight like 20 tons or 40 tons, but in specific cases vehicles down to 1 ton can also be detected.

This comprehensive counting and weighing of all significant vehicles gives an accurate insight of the actual level of traffic on the bridge. Maintenance schemes can be optimized accordingly, and over-weight trucks can easily be counted, timestamped and their exact effect on the bridge structure is accurately assessed. The WIM+D system provides both weight estimation and structure assessment with the same sensors, as its philosophy is to use the strain variations in the most critical parts of the bridge for the weight estimation.

Traffic statistics are displayed on the Safe WIM+D web interface and updated in real time for each new truck detected (Figure 8). The passages are sorted by timestamp, gross weight or direction.

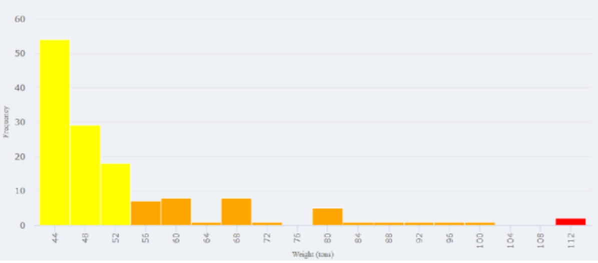


Figure 8. Traffic Statistics as displayed on the Safe WIM+D web interface

The OSMOS WIM+D system enables an accurate and comprehensive knowledge of the real level of traffic on the bridge, which leads to efficient maintenance schemes and relevant input data for a lifetime estimation through fatigue analysis.

IV. LIFETIME ESTIMATION THROUGH FATIGUE ANALYSIS

A. *Methodology for Fatigue Analysis*

Fatigue is the phenomenon by which progressive micro defects inside a material like steel merge into cracks until fragile failure of the structure, under the effect of repeated load cycles. In the case of road bridges, these cycles are of very low amplitude compared to the limit state of the material, so the methodology for fatigue in this case is the High-Cycle Fatigue (HCF) analysis, suitable for more than 10,000 cycles before failure (Ye *et al.*, 2014).

In the case of HCF analysis, the theoretical number of cycles depending on their amplitude until deterioration is given by “S-N” curves which are available in most national standards for steel structure design.

Because Fatigue is due to stress cycles, Optical Strands are well dedicated to monitor the accumulation of cycles over long durations, as they do measure strain which is easily converted into stress in the case of steel structures.

The first step of a fatigue analysis methodology from on-field measurement is to count and sort the stress cycles by amplitude. This counting has been performed in the case of the pilot project already mentioned for the WIM+D by a usual Rainflow counting algorithm.

The second step is to choose a detail category for each monitored part of the bridge deck, depending on its configuration structure (welding, bolts, specific shapes…). The Detail Category defines the S-N curve to be chosen. Considering that the bridge of the study is an old structure with already evident corrosion of the main girders, a very conservative hypothesis has been chosen with the detail category 36 of the European standard Eurocode 3. Note that, for this case, no laboratory test results were available in order to quantify more precisely the fatigue limit of the steel elements. This is a common situation, because it is difficult to accept the removal of a sample on an already damaged bridge.

Once the S-N fatigue limit curve is chosen, for each measured stress cycle of range $\Delta\sigma$, the corresponding limit number of cycles N is computed from the S-N curve, and the consecutive damage rate is 1/N. Following the Palmgren-Miner rule, the damage rates of all cycles are added in order to get the effective damage rate over defined periods of time (like each day or for the whole duration of the monitoring).

The analysis of the total damage rate computed each day and its progression along the monitoring period allows an anticipation of the time when the total rate will reach the value 1, which is the theoretical lifetime of the structure regarding fatigue criteria.

B. *Cumulative Damage and Lifetime Estimation*

The Fatigue assessment has been performed on the above-mentioned composite deck bridge, on 12 different critical locations of the steel main beams. 4 of them are parts of the lower flanges at mid-span, where the tension stress is maximal. The 8 remaining locations are near to the abutments and the Optical Strands were installed in diagonal, in order to record the principal strain variations due to shear effects near to the bearing points. This strain is directly linked to the maximal shear stress in the webs.

First of all, all the strain cycles in a 6 month duration have been recorded and classified by a Rainflow algorithm. The results are as follows, for one of the sensors, with one strain cycle distribution computed for every day (Figure 9).

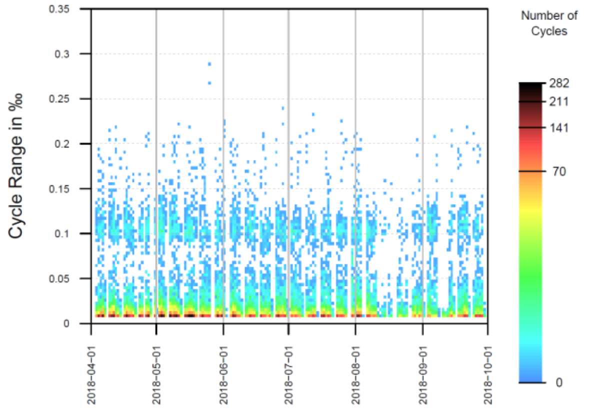


Figure 9. Rainflow Strain Cycle Counting and Classification for a 6 month long continuous monitoring period

Figure 9 shows that there were numerous very low amplitude cycles below 0.05‰ range, which correspond to vibrations of the bridge deck. In addition, we see a cluster of ranges around 0.12‰ which correspond to typical heavy trucks passages. The maximal strain range recorded in this 6 months long continuous monitoring period is 0.29‰ which is an exceptional convoy.

The second step is to convert these strain cycles into stress cycles and to compute the related damage rate, for each recorded cycle.

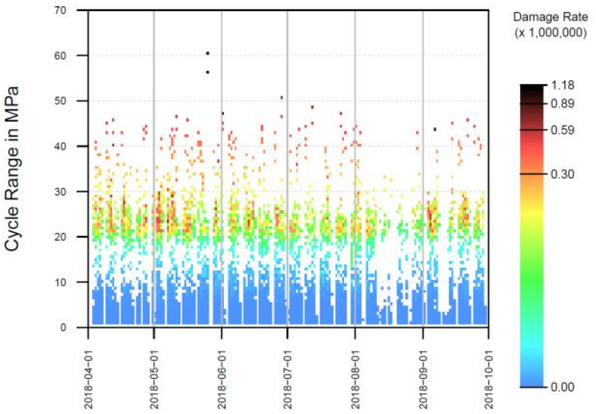


Figure 10. Stress Cycles and Damage Rates for a 6 month long continuous monitoring period

The S-N curve emphasize the higher ranges dramatically: all stress cycles below 10 MPa (equivalent to strain cycles below 0.05‰) have a null damage rate, whereas the heaviest cycle with a range of 61 MPa reaches a damage rate of 1.18ppm, which means this part of the structure would fail by fatigue after 0.85 millions of such cycles (Figure 10).

Once the damage rate is computed for each cycle, its accumulation along the monitoring period enables to know precisely the kinetics of fatigue damage on the structure (Figure 11).

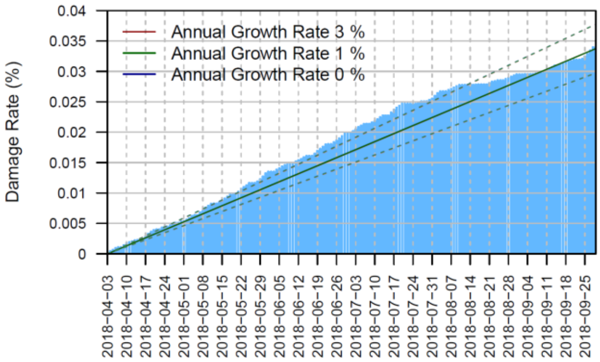


Figure 11. Cumulative Damage Rate for a 6 month long continuous monitoring period

On a 6 months duration, the Fatigue Damage of this part of the structure has increased by 0.035%, with some seasonal variations (less traffic in August).

This increase of the Fatigue Damage is then extrapolated into the future and the past in order to estimate the remaining fatigue lifetime of the bridge, depending on assumptions on the traffic growth rate in the long term.

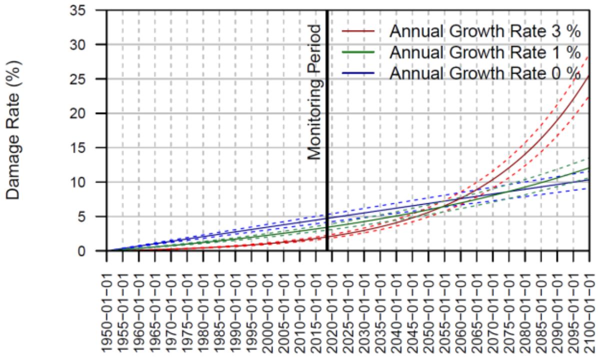


Figure 12. Extrapolation of the Damage Rate Growth

As the slope of the Fatigue Damage has been precisely estimated over the monitoring period, the extrapolation is reliable and well controlled by confidence intervals (dashed lines on Figure 12). In our case, the worse assumption on traffic growth rate with 3% each year induces a total fatigue damage below 30% in year 2100 and the remaining fatigue lifetime is estimated at 124 years.

V. SUMMARY AND CONCLUSIONS

In order to address the challenge of optimizing the exploitation and maintenance of ageing road bridges, the continuous strain assessment of critical parts of the bridge structure by Optical Strands is a relevant solution which enables several different applications with a single monitoring system.

The first application is the design check from the results of load tests. In this context, strain measurements are directly linked to stress levels and material behavior, more than the usual deflection measurements. In addition, the high sampling rate of the strain measurements enables to perform both static and dynamic testing with the same monitoring system and the same Optical Strands sensors. The use of a rating factor allows a very accurate assessment of the bridge.

The second application is the traffic assessment through an efficient Weigh-In-Motion solution, using the same sensors than the design check. Overweight traffic detection and traffic statistics are performed in real time and released remotely on a web interface to allow everyday management of the road bridge.

Finally, the comprehensive counting of strain cycles due to the traffic through the continuous long-term monitoring by Optical Strands enables highly relevant fatigue analysis of steel and composite bridges. Unlike the usual methodology for fatigue assessment which considers samplings of a few days or weeks, the OSMOS methodology takes into account every single stress cycle over very long periods of several months or years in order to reduce the uncertainty on the fatigue lifetime estimation.

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